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(54) **FERROELECTRIC EMITTER**

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(52) **U.S. Cl.** ...................... **313/310**; 313/495; 313/311; 313/309; 313/351

(58) **Field of Search** ................................ 313/495, 497, 313/310, 311, 309, 336, 351

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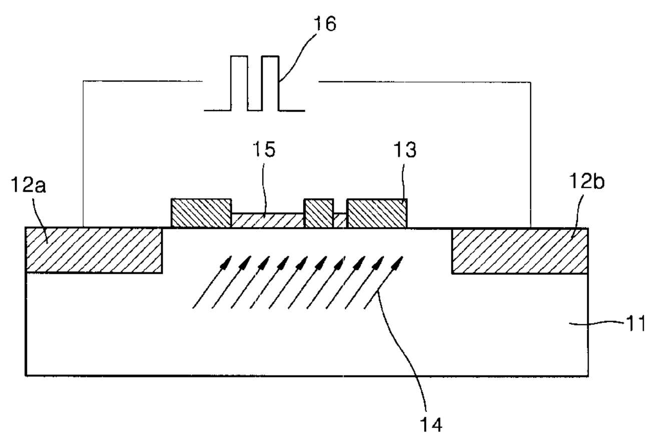
(57) **ABSTRACT**

A ferroelectric emitter is described. The ferroelectric emitter of the present invention includes a ferroelectric layer having a first side, an opposing second side, and a top surface, a first and a second electrode formed along the top surface of the ferroelectric layer, and a mask layer which has a predetermined pattern and is formed along the top surface of the ferroelectric layer between the first and second electrodes. When used in ferroelectric switching emission lithography, the ferroelectric emitter of the present invention allows electron emission from a wide or narrow gap of a mask layer and from an isolated pattern such as a doughnut shape while facilitating re-poling in pyroelectric electron emission.

**6 Claims, 2 Drawing Sheets**



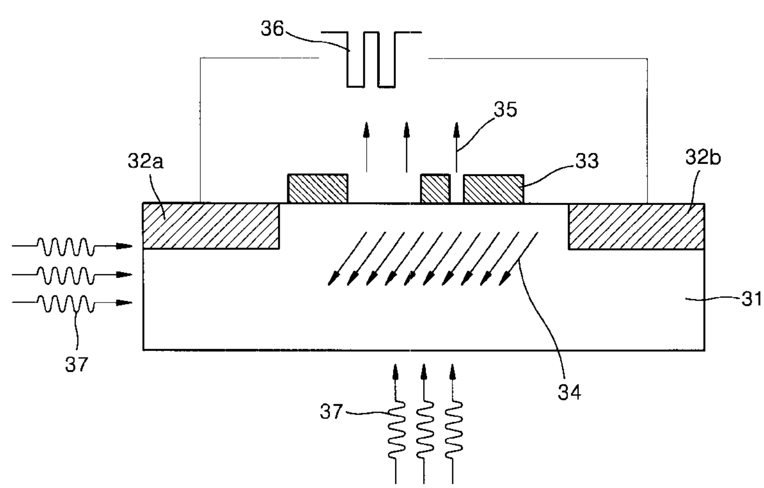



FIG. 1

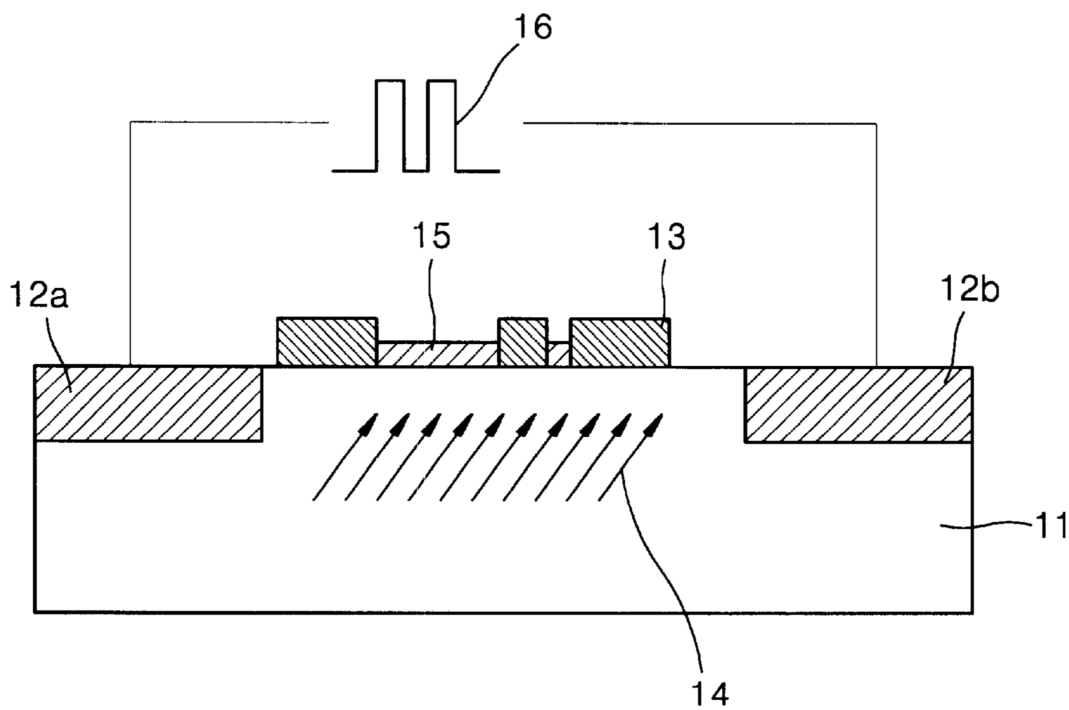



FIG. 2

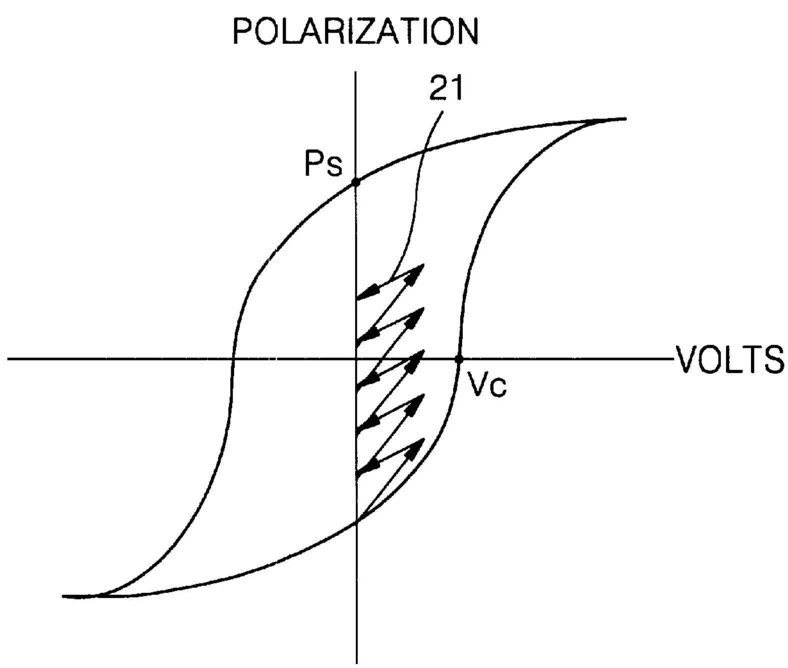


FIG.3

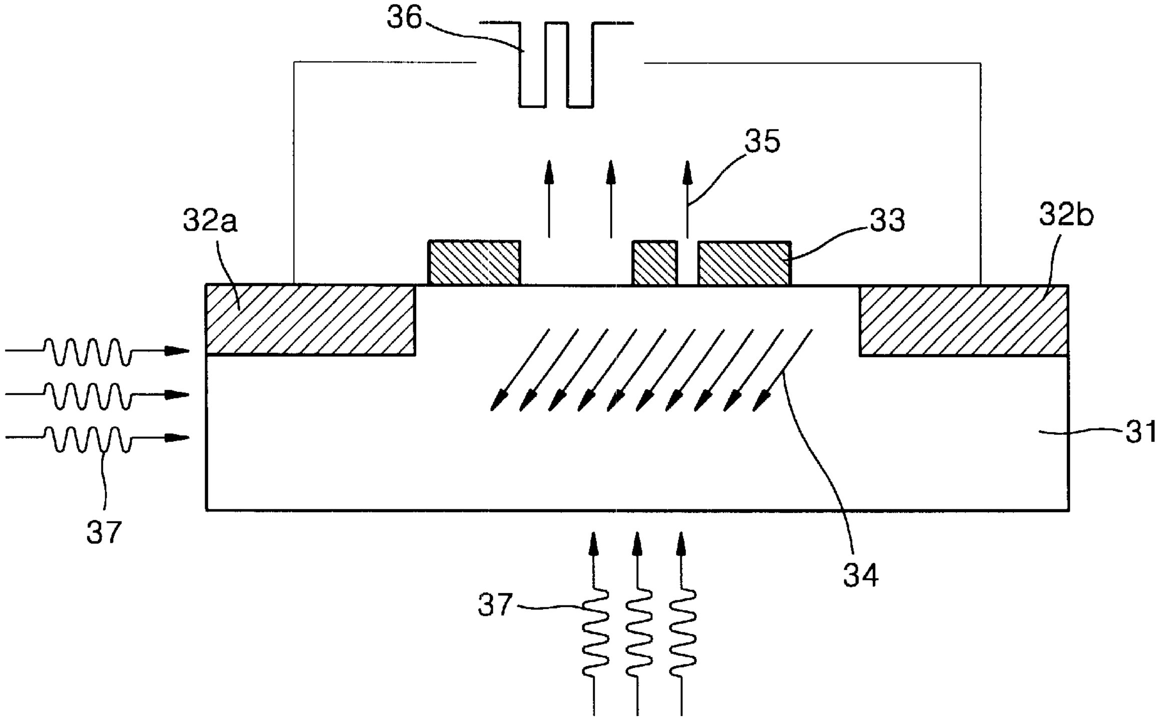
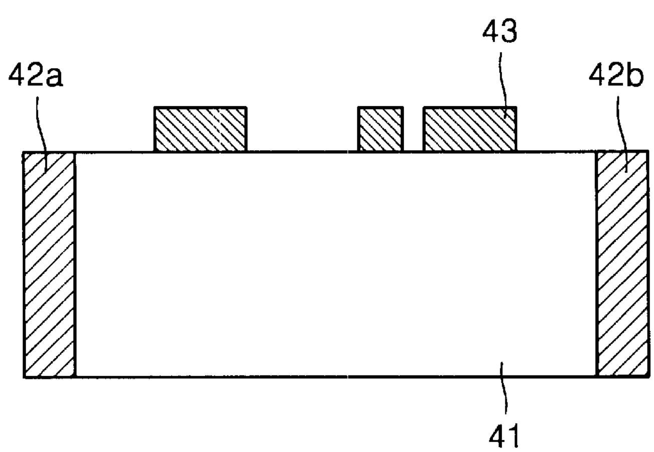



FIG.4



# FERROELECTRIC EMITTER

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a ferroelectric emitter. More specifically, the present invention relates to a side electrode emitter in which electrodes are attached to the top surface or at side edges of a ferroelectric layer.

2. Description of the Related Art

Ferroelectric emission by switching allows for a simple process in electron emission lithography. In the past, electron emission suitable for lithography has been obtained by applying an external magnetic field or heat. However, a conventional ferroelectric emitter cannot guarantee electron emission where the distance between two electrodes for applying a power is too wide or too narrow for switching.

For example, in the conventional ferroelectric emitter, if the distance between the two electrodes is too wide, then an electric field cannot reach the center portion of the ferroelectric emitter. Thus, a switching effect does not occur in a ferroelectric region. If, on the other hand, the distance between the two electrodes, or a gap of a mask pattern, is too narrow, then the mask pattern formed on a ferroelectric layer in a ferroelectric emitter absorbs electrons during electron emission, so that electrons flow through the patterned mask. Moreover, an isolated pattern, such as a doughnut shape, cannot be switched because the two electrodes are not connected to each other.

In contrast to ferroelectric switching, pyroelectric emission can provide a uniform emission of electrons regardless of the characteristics of a gap of a mask pattern. Pyroelectricity refers to the production of polarization changes by temperature variations. Due to such properties, when a material is subjected to a temperature change, the magnitude of a spontaneous polarization changes to affect bound charges, so that a current flows through electrodes.

If an emitter is heated and this process occurs in a vacuum, then bound charges, which are electrons screening on the surface of the emitter, are released in a vacuum, which is called pyroelectric emission. In this case, uniform emission is allowed whether a gap of the mask pattern is wide or narrow. Furthermore, pyroelectric emission enables electron emission in an isolated pattern such as a doughnut pattern. Although it facilitates electron emission, pyroelectric emission has several disadvantages. One of these disadvantages is the requirement of re-poling or heating the emitter above the Curie temperature for re-emission.

## SUMMARY OF THE INVENTION

A feature of the present invention is to provide a ferroelectric emitter that allows electron emission in both wide and narrow gaps of a mask layer and in an isolated pattern such as a doughnut shape for ferroelectric switching emission lithography, while facilitating re-poling in pyroelectric emission.

The present invention provides a ferroelectric emitter including: a ferroelectric layer having a first side and an opposing second side and a top surface, a first electrode formed adjacent the first side and the top surface of the ferroelectric layer, a second electrode formed adjacent the opposing second side and the top surface of the ferroelectric layer; and a mask layer having a predetermined pattern and formed along the top surface of the ferroelectric layer between the first and second electrodes.



In a preferred embodiment of the present invention, the mask layer is formed by exposing a predetermined region of the top surface of the ferroelectric layer, and the orientation of the crystal lattice of a ferroelectric material of the ferroelectric layer is developed so as to form an acute angle with the direction of an electric field induced when a voltage is applied to the electrodes.

The present invention also provides a ferroelectric emitter including: a ferroelectric layer having a first side and an opposing second side and a top surface, a first electrode formed along the first side edge of the ferroelectric layer, a second electrode formed along the opposing second side edge of the ferroelectric layer, and a mask layer having a predetermined region and formed along the top surface of the ferroelectric layer.

In another preferred embodiment of the present invention, the mask layer is formed so as to expose a predetermined region of the top surface of the ferroelectric layer, and the orientation of the crystal lattice of a ferroelectric material of the ferroelectric layer is developed so as to form a predetermined angle with the direction of an electric field induced when a voltage is applied to the electrodes.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above-described features and advantages of the present invention will become more apparent by describing in detail a preferred embodiment of the present invention with reference to the attached drawings in which:

FIG. **1** is a cross-sectional view showing the structure of a ferroelectric emitter of the present invention having a first and a second electrode formed along the top surface and adjacent the first and second sides of a ferroelectric layer, respectively;

FIG. **2** is a graph of polarization vs. volts showing that the ferroelectric emitter according to the present invention reaches a maximum polarization value when the emitter continues partial switching;

FIG. **3** is a cross-sectional view showing that pyroelectric emission is performed by applying heat to the ferroelectric emitter; and

FIG. **4** is a cross-sectional view showing the structure of a ferroelectric emitter of the present invention having a first and a second electrode formed along the first and opposing second side edges of a ferroelectric layer, respectively.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. **1**, an emitter according to the present invention includes a ferroelectric layer **11** comprised of a ferroelectric material, and a first electrode **12***a* and a second electrode **12***b* formed adjacent a first side and an opposing second side of the ferroelectric layer **11** along the top surface of the ferroelectric layer **11**. Further, a mask layer **13** is formed between the first electrode **12***a* and second electrode **12***b* . The mask layer **13** is formed so as to expose a predetermined region of the top surface of the ferroelectric layer **11**, which is an amount less than the entire top surface of the ferroelectric layer **11**.

When a voltage is applied to the first electrode **12***a* and second electrode **12***b,* the ferroelectric layer **11** becomes polarized. The crystal lattice structure of a ferroelectric material forms a predetermined angle with the direction of an electric field to cause partial switching. Put another way, the ferroelectric layer **11** is formed so that the electrical field and the polarization **14** are produced in a horizontal direction and in an oblique direction, respectively, when a voltage is applied to the first electrode **12***a* and second electrode **12***b*.

The method of operation of the ferroelectric emitter according to the present invention will now be described. In order to collect electrons in a mask layer **13**, a unipolar pulse **16** is applied to a first electrode **12***a* and a second electrode **12***b* so that the direction of polarization **14** is as shown in FIG. **1**, considering the orientation of a ferroelectric material crystal lattice. For example, a positive voltage pulse **16** is shown in FIG. **1**.

In general, when a voltage is applied to both sides of the ferroelectric layer **11**, partial switching occurs. Partial switching occurs when the applied voltage does not exceed a coercive voltage $V_c$, which is required for completely polarizing a ferroelectric material. However, as shown in FIG. **2**, although the applied voltage does not go beyond the coercive voltage $V_c$, if the applied voltage is repeatedly applied to achieve partial switching, the polarization increases toward a maximum polarization value, Ps. When polarization occurs, screening charges **15**, for compensating for the net electric dipole, are formed on the surface area of the ferroelectric layer **11**. The screening charges **15** in FIG. **1** are electrons.

For electron emission in a ferroelectric emitter, electrons on the ferroelectric surface area, which are the screening charges, have to be emitted. In order for electrons to be emitted, the ferroelectric layer **11** of the present invention must be subjected to opposite switching or heating.

Referring now to FIG. **3**, opposite switching for a ferroelectric layer **31** will be described. First, in order to emit screening charges **35** from between patterns of a mask layer **33** overlying the ferroelectric layer **31**, a pulse **36** of opposite polarity to the previously applied unipolar pulse **16**, discussed in connection with FIG.**1**, is continuously applied to the first and second electrodes **32***a* and **32***b*, respectively. In this case, screening charges **35**, or electrons, between patterns of the mask layer **33** overlying the ferroelectric layer **31** are increasingly emitted from the mask layer **33** to a collector or electron resist, to which voltages of the first electrode **32***a* and second electrode **32***b* are applied, by the applied unipolar pulse **36**.

Electron emission is gradually achieved by the repeatedly applied pulse **36**, or as another electron emission method, heat **37**, is applied to the ferroelectric emitter. Heating may be accomplished by a heater, laser, infrared rays, or the like, thereby allowing pyroelectric emission. Furthermore, the initial positive voltage pulse **16** is applied to perform screening on the electrons **35**, which are positioned between patterns of the mask layer **33** overlying the ferroelectric layer **31** after electron emission.

Referring now to FIG. **4**, another embodiment of the present invention will be described. In this embodiment, electrodes **42***a* and **42***b* are formed on two opposing sides of a ferroelectric layer **41**, a first side and a second side. This embodiment includes the electrodes **42***a* and **42***b* formed on the first and second sides of the ferroelectric layer **41** and a mask layer **43** having a pattern formed on the ferroelectric layer **41**. The mask layer **43** is formed so as to expose a predetermined region of the top of the ferroelectric layer **41**, which is not the entire top surface of the ferroelectric layer **41**. Therefore, a difference between the ferroelectric emitter of FIG. **1** and the ferroelectric emitter of FIG. **4** is in the region where electrodes are formed.

The method of operation of the ferroelectric emitter as shown in FIG. **4** is no different from the method of operation of the emitter as shown in FIG. **1**. More specifically, a unipolar pulse is applied to the first electrode **42***a* and second electrode **42***b*, considering the orientation of a ferroelectric material crystal lattice so that electrons may be collected between patterns of the mask layer **43** formed on a top center portion of the ferroelectric layer **41**. Then, if polarization occurs, screening charges are created on the surface area of the ferroelectric layer **41** to compensate for the electric dipole.

After the screening charges are created, a pulse of opposite polarity to that of the initially applied unipolar pulse is continuously applied in order to emit the screening charges produced between patterns of the mask layer **43** overlying the ferroelectric layer **41**. In this embodiment, screening charges, which are electrons, positioned between patterns of the mask layer **43** overlying the ferroelectric layer **41** are gradually emitted from the mask layer **43** to a collector by the unipolar pulse. Furthermore, heat is applied to the ferroelectric emitter from the outside in order to enable pyroelectric emission. Additionally, to induce screening charges between patterns of the mask layer **43** overlying the ferroelectric layer **41** after electron emission, the initial pulse is applied to the first electrode **42***a* and second electrode **42***b* again.

The present invention allows electron emission in a wide or narrow region for ferroelectric emission lithography and in an isolated pattern such as a doughnut shape, while facilitating re-poling in pyroelectric emission. Accordingly, the present invention provides a ferroelectric emitter having many applications.

What is claimed is:

**1**. A ferroelectric emitter comprising:

a ferroelectric layer having a first side, an opposing second side and a top surface;

a first electrode formed at the top surface and adjacent to the first side of the ferroelectric layer;

a second electrode formed at the top surface and adjacent to the opposing second side of the ferroelectric layer;

a mask layer having a predetermined pattern is formed along the top surface of the ferroelectric layer between the first and second electrodes.

**2**. The ferroelectric emitter as claimed in claim **1**, wherein the mask layer is formed by exposing a predetermined region of the top surface of the ferroelectric layer.

**3**. The ferroelectric emitter as claimed in claim **1**, wherein the ferroelectric layer further comprises a crystal lattice having an orientation and a voltage being applied to the first and second electrodes and inducing an electric field having a direction; and

the orientation of the crystal lattice of a ferroelectric material of the ferroelectric layer is developed so as to form an acute angle with the direction of the electric field induced when the voltage is applied to the electrodes.

**4**. A ferroelectric emitter comprising:

a ferroelectric layer having a first side edge, an opposing second side edge, and a top surface;

a first electrode formed along the first side edge of the ferroelectric layer;

a second electrode formed along the opposing second side edge of the ferroelectric layer; and

a mask layer having a predetermined region is formed along the top surface of the ferroelectric layer between the first and second electrodes.

**5**. The ferroelectric emitter as claimed in claim **4**, wherein the mask layer is formed so as to expose a predetermined region of the top surface of the ferroelectric layer.

**6**. The ferroelectric emitter as claimed in claim **4**, wherein the ferroelectric layer further comprises a crystal lattice having an orientation and a voltage being applied to the first and second electrodes and inducing an electric field having a direction; and

the orientation of the crystal lattice of a ferroelectric material of the ferroelectric layer is developed so as to form a predetermined angle with the direction of the electric field induced when the voltage is applied to the electrodes.

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